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VERIFICATION OF TRANSLATION

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declare as follows

1. That I am well acquainted with both the English and French languages, and

2. That the attached document is a true and correct translation made by me to the best of my knowledge and belief, of

   the patent application entitled:

   PLASMA SOURCE OF DIRECTED BEAMS AND APPLICATION THEREOF TO MICROLITHOGRAPHY

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PLASMA SOURCE OF DIRECTED BEAMS AND APPLICATION THEREOF TO MICROLITHOGRAPHY

This present invention concerns the generation of radiation at a desired wavelength.

More precisely, the invention concerns a process for the generation in a given direction of radiation emissions in a desired range of wavelengths, where the said process includes:

- the production of initial radiation by a radiation source whose wavelengths includes the said desired range,
- filtering of the said initial radiation, so as to substantially eliminate the part of the initial radiation whose wavelength is outside the said desired range.

The invention also concerns a radiation generating device that can be used to implement such a process, as well as a lithography device incorporating such a generation device.

We are already familiar with processes and devices of the type mentioned above.

One (non-limiting) example of implementation thus concerns the generation of radiation at a desired wavelength intended for an optical chain, for lithography applications on a photosensitive substrate. Figure 1 thus diagrammatically illustrates an optical system 100, that consists of the following in succession:

- a generator 10 of radiation in a desired range of wavelengths,
- a lens assembly 11 which receives the radiation coming from the generator 10 and processes it (e.g. by subjecting it to collimation and/or focussing of its beams),
- a mask 12 which receives the processed radiation coming from the lens assembly, and selectively allows to pass only the beams arriving at the mask via a transmission

pattern 120, with the remainder of the radiation being stopped by the mask.

- a substrate 13 which receives the beams that have been transmitted by the mask, and whose surface exposed to the radiation bears a photo-resistant or photosensitive product.

The beams arriving at the substrate react with the product and thus form, on the surface of the substrate, a pattern that matches the transmission pattern of the mask.

The desired range of wavelengths of the generator 10 can in particular be located in the ultra-violet (UV) spectrum, or in the extreme UV (EUV) spectra.

Note that in this text, we conventionally use the term "EUV" to refer to both the EUV beams and soft x-rays.

The EUV beams are associated with very short wavelengths (less than 100 nm, and of the order of a few tens of nms for example, where an application corresponds to a wavelength of 13.5 nm). This is advantageous in particular for photolithography applications, since in a corresponding manner, the patterns drawn by the beams can be of very small dimensions. In particular, this allows the formation of a larger quantity of patterns on a substrate of the same size.

It is necessary however to associate radiation filtering resources with the radiation generator.

In fact in certain cases - in particular for radiation generators whose wavelength is in the EUV range - the generator includes a radiation source of the plasma source type.

Now in addition to the desired radiation, such radiation sources also emit:

- radiation whose wavelengths do not correspond to the desired range, and/or

- solid debris resulting from the interaction between the plasma and solid parts of the chamber in which this plasma is located (target, walls of the chamber, etc.).

In order to isolate, in the radiation coming from the source of the generator, only the beams that are at a desired wavelength, it is therefore necessary to provide filtering resources downstream of the source (e.g. immediately downstream of the source, in order to avoid exposing the mask to debris which could damage it).

In a known manner, such filtering resources include a multi-layer mirror which selectively reflects the beams according to their wavelength.

Such a multi-layer mirror thus functions as a band-pass filter.

It obviously does not pass on the undesirable debris which can be emitted by the source, so that the elements located downstream of the filtering resources are not exposed to such debris.

Such a solution actually allows filtering out of the beams emitted by a radiation source that is liable to produce such debris.

However one drawback associated with such a known configuration is that the debris emitted by the source can damage the mirror of the filtering resources.

Of course it would be possible to envisage distancing the said filtering resources from the source, so as to reduce the probability that debris will damage the mirror of these filtering resources.

In this case however, there would be a significant reduction in the radiation stream recovered by the filtering resources, thus adversely affecting the performance of the whole optical system.

It therefore appears that the known configurations for generating radiation at a desired wavelength are associated with drawbacks when the radiation source is liable to generate debris.

In particular, this disadvantage concerns applications in which the desired wavelengths fall in the EUV area.

The aim of the invention is to enable one to get around these drawbacks.

In order to attain this objective, the invention proposes, according to a first aspect, a process for the generation, in a given emission direction, of radiation in a desired range of wavelengths, where the said process includes:

- the production of initial radiation by a radiation source, whose wavelengths include the said desired range,
- filtering of the said initial radiation, so as to substantially eliminate the beams of the initial radiation whose wavelength is outside the said desired range,

characterised in that the said filtration is achieved by introducing a controlled distribution of the refraction index of the beams in a control region that is traversed by the initial radiation, so as to selectively deflect the beams of the initial radiation according to their wavelength, and to recover the beams of a desired wavelength.

Preferred, though not limiting, aspects of such a process are as follows:

- the said controlled distribution of the refraction index of the beams is obtained by controlling the density distribution of electrons in the said control region,
- the said control region is located in a plasma,
- the said plasma containing the said control region is itself contained in a chamber associated with the said radiation source,

- electron density control is effected so as to obtain an electron density which is greater at a distance from a median initial radiation emission line than it is on the said median emission line of the initial radiation,

- the said median initial radiation emission line is a straight initial radiation line, and the said initial radiation is produced by the said radiation source with a more or less axi-symmetrical distribution around the said straight initial radiation line,

- in order to obtain the said electron density distribution, an input of energy is applied to the said plasma along the said median initial radiation emission line,

- the said energy input is effected by ionisation of the plasma along the said median initial radiation emission line,

- in order to effect the said ionisation, the following operations are required:

  - establishment of an electrical voltage at the terminals of the chamber containing the plasma, the said terminals being spaced in the general direction defined by the said median initial radiation emission line,

  - application of an energy beam to said median initial radiation emission line,

- in order to recover the beams of a desired wavelength, there is at least one window downstream of the said control region, to selectively pass beams in the desired wavelength range,

- each window is positioned on the said median initial radiation emission line, with a curvilinear abscissa corresponding to the place of intersection of the said beams in the desired wavelength range which were deflected with the said median initial radiation emission line,

- the said desired range of wavelengths falls within the interval [0-100 nm],

- the said desired range of wavelengths falls within the EUV spectrum.

According to a second aspect, the invention also proposes a device for the generation, in a given emission direction, of radiation in a desired range of wavelengths, where the said device includes:

- a source of initial radiation whose wavelengths include the said desired range,

- filtering resources of the said initial radiation, so as to substantially eliminate the beams of the initial radiation whose wavelength is outside the said desired range,

characterised in that the said filtering resources include the means to introduce a controlled distribution of the refraction index of the beams in a control region that is traversed by the initial radiation, so as to selectively deflect the beams of the initial radiation according to their wavelength, and to recover the beams of a desired wavelength.

Preferred, though not limiting, aspects of such a device are as follows:

- the said means to introduce a controlled distribution of the refraction index includes resources to control the electron density distribution in the said control region,

- the said control region is located in a plasma,

- the said plasma containing the said control region is itself contained in a chamber associated with the said radiation source,

- the said resources to control the electron density distribution are capable of achieving an electron density which is greater at a distance from a median initial

radiation emission line than it is on the said median initial radiation emission line,

- the said median initial radiation emission line is a straight initial radiation line, and the said resources to control the electron density distribution are capable of achieving an electron density that is more or less axi-symmetrical around the said straight initial radiation line,

- the said resources to control the electron density distribution include resources for injecting energy into the said plasma along the said median initial radiation emission line,

- the said resources for injecting energy include resources for ionisation of the plasma along the said median emission line of the initial radiation,

- the said resources for injecting energy include resources to:

  - establish an electrical voltage at the terminals of the chamber containing the plasma, with the said terminals being spaced in the general direction defined by the said median initial radiation emission line,

  - apply an energy beam to said median initial radiation emission line,

- downstream of the said control region, the device includes at least one window to selectively pass beams in the desired wavelength range,

- each window is positioned on the said median initial radiation emission line, with a curvilinear abscissa corresponding to the place of intersection of the said beams in the desired wavelength range, which were deflected with the said median initial radiation emission line,

- the device includes an additional multi-layer filtration mirror in association with at least some windows,

- the device includes a multiplicity of modules, which each include a source of initial radiation and associated filtering resources, as well as an optical resource that can be used to collect the radiation subjected to filtration, in order to re-direct it outside of the device.

- the said optical resource is a multi-layer mirror which is also capable of finalising filtering of the said radiation,

- the said desired range of wavelengths falls within the interval [0-100 nm],

- the said desired range of wavelengths falls within the EUV spectrum.

The invention finally concerns a lithography device that includes a generation device according to one of the above aspects.

Other aspects, objectives and advantages of the invention will appear more clearly on reading the following description of the invention, which is provided with reference to the appended drawings on which, apart from figure 1 which has already been described above:

- figure 2 is a schematic diagram of a radiation generator according to the invention,

- figure 3 is a similar representation, illustrating an electron density distribution which is controlled in a particular manner in the context of the invention,

- figure 4 illustrates a particular method of implementation of the invention with a multiplicity of radiation sources.

Figure 2 diagrammatically illustrates a radiation generator 20 according to the invention.

This radiation generator includes a chamber 21 which is generally closed but with one side 210 open to let pass the beams emitted by the chamber.

The chamber 21 includes a source 211 that is capable of producing initial radiation R0.

Typically this is a source containing a plasma.

The initial radiation includes beams whose wavelength corresponds to a desired range of wavelengths.

In a preferred but not limiting application of the invention, the desired range of wavelengths falls within the interval [0-100 nm].

This desired range of wavelengths can thus be located in the EUV spectrum.

The chamber 21 is thus capable of producing initial radiation in which a significant quantity of beams correspond to the desired wavelength range.

As mentioned previously, it is possible however that undesirable effects can be associated with the emission from the source:

- the initial radiation can also contain beams whose wavelengths do not correspond exactly to the desired range,
- and it is also possible that the source 211 may emit a certain amount of debris with the initial radiation.

In order to prevent these undesirable effects, the generator 20 includes resources for filtering the initial radiation.

These filtering resources are capable of introducing a controlled distribution of the refraction index of the beams in a control region 212 traversed by the initial radiation, so as to selectively deflect the beams of the initial radiation according to their wavelength.

The beams of a desired wavelength are then recovered (in particular using resources which will be described in this text).

We are thus making use of a physical principle similar to that, for example, which causes the deflection of light beams

in the presence of a gradient of the refraction index of the air (the particular case of air with high temperature gradients).

In the case illustrated in figure 2, the control region is located inside of the chamber itself 21.

Note that it is also possible for this control region to be located outside the chamber 21, downstream of the latter on the trajectory of the initial radiation.

Control of the distribution of the refraction index in the control region can be achieved by controlling the electron density distribution in the said control region.

In this regard, it is in fact possible to exploit the relationship linking the refraction index η to the electron density n_e:

$\eta = (1 - n_e/n_c)^{1/2}$, where n represents a critical electron density value beyond which the beams are no longer able to pass, since this value of n_c is related to the wavelength of the beams concerned).

Returning to the method of implementation illustrated in figure 2, the control region 212 is therefore located in the chamber 21, and this control region is thus in the plasma associated with the source 211.

Control of the electron density distribution in the control region allows one to influence the trajectories of the different beams of the initial radiation, according to the wavelength of these beams. This is illustrated in figure 2, which shows two general trajectories of two types of beam:

- beams of a first wavelength $\lambda 1$. These beams have the trajectory R1.
- beams of a second wavelength $\lambda 2$, which is shorter than the first wavelength $\lambda 1$. These beams have the trajectory R2.

In the preferred application of the invention which is illustrated here, an electron density distribution is established in the control region such that the electron density is greater at a distance from a median initial radiation emission line than it is on the said median initial radiation emission line.

The "median initial radiation emission line" corresponds, in the case of figure 2, to the straight line A. Note that in the case illustrated here, the chamber is typically in the shape of a round cylinder, and that the initial radiation is emitted with a more or less axi-symmetrical distribution of the beams, around line A.

The configuration of the electron density distribution desired in this case is illustrated diagrammatically in figure 3, which shows electron density curves.

In this figure, it can be seen that the electron density value is greater at the edges of the chamber (distanced from line A) than in the middle of this chamber (close to line A).

It can also be seen that the three electron density curves that are shown diverge in the peripheral region of the chamber. We will come back to this aspect.

It will be seen that such an electron density distribution is opposite to the electron density distribution that can normally be observed in the chamber of a radiation source.

In the case of a chamber of known type, in fact one generally observes a higher density at the centre of the chamber.

The density configuration shown in figure 3 is therefore specific, and it is created by design for the application of the invention described here. In order to create such an electron density distribution in the control region, energy is

injected into the plasma of the chamber 21 along the said line A.

This input of energy can be effected, for example, by a beam of electrons or by a laser beam, directed into the control region along the axis defined by line A.

This input of energy is illustrated diagrammatically by arrow E. It is used to ionise the plasma in the control region, along line A.

Prior to this input of energy, it was possible to establish an electric voltage at the terminals of the chamber containing the plasma, the said terminals being spaced along the general direction defined by the said median initial radiation emission line.

Figure 3 diagrammatically represents such terminals 2121 and 2122.

It is thus possible to create an electron density distribution of the type of those shown in figure 3.

Note that such a distribution can be obtained by starting from a density distribution of known type, in which the density is higher at the centre of the chamber.

The input of energy and the ionisation associated with it is in fact used in this case to "invert" the density configuration, and to obtain a higher density close to the peripheral walls of the chamber.

Figure 3 shows three density distribution curves as mentioned.

These three curves are more or less coincident in the central region of the chamber (close to line A), but have different values of density close to the walls of the chamber.

These three curves correspond to successive states of the electron density distribution, when ionisation of the central zone of the control region has been effected.

At the end of such an ionisation, we find an electron density which is already higher at the periphery of the control region.

If, however, one then allows the plasma thus ionised to develop, this configuration will then become accentuated, and the value of the density will again increase at the periphery. In fact the high-density electrons present in great quantity at the periphery of the chamber will have a tendency to cause the internal walls of this chamber to melt, single layer of wall coating by single layer of wall coating.

This melting leads to an additional input of electrons at the periphery of the chamber, which still further increases the electron density in this area.

Figure 2 specifically represents a window 222 which is positioned at the focal point of the beams on the trajectory R2.

This window corresponds to a resource for recovery of beams of a desired wavelength, from amongst the beams of the initial radiation.

It has been seen that the different beams emitted by the initial radiation R0 were deflected in a different manner, by the electron density distribution which existed in the control region, according to their wavelength.

This selective deflection causes the beams associated with a given wavelength to converge toward a specific point on line A - which we will call the "focal point".

The position of the focal point on line A (a position that can be defined by a curvilinear abscissa of a marker linked to the said line A) therefore depends on the wavelength associated with this focal point.

Figure 2 shows focal points FI and F2 associated respectively with the beams of trajectories R1 and R2.

The window 222 is thus positioned at focal point F2. The function of this window is to allow to pass only the beams arriving at line A more or less at focal point F2 (that is the beams of wavelength λ2. To this end, window 222 includes an opening 2220 which is preferably centred on line A.

This window thus constitutes an advantageous resource for recovering only the beams of a desired wavelength. It thus improves filtration of the beams emitted by the initial radiation.

In this way, it is possible to have windows in any desired position on line A, according to the wavelength that one wished to isolate.

It can therefore be seen that the invention allows beams of a desired wavelength (or at desired wavelengths, to be exact) to be isolated in an efficient manner.

And in the case of the invention, one is not exposing a filtration resource, such as a multi-layer mirror, to debris that is liable to damage it.

In the case of the invention, the fact that the desired beams are recovered at a specific point toward which they were deflected already allows a large part of any debris emitted by the source 21 to be avoided.

Implementation of recovery resources such as a window allows the quantity of debris to be reduced still further.

The result is that at the end of this filtration, there is no debris at all - or very little in any case.

Note that downstream of the focal point of the beams that need to be recovered, it is possible to create resources for optical conditioning of the beam formed by these filtered beams.

In particular, this optical conditioning can be a collimation and/or a focussing process.

The recovered beam can therefore be sent directly toward a lithography mask.

It is also possible to direct the recovered beam toward additional filtering resources, if so desired.

Such additional filtering resources can include a multi-layer mirror like those which constitute the filtering resources that are known currently.

The layers of such a multi-layer mirror are designed (in composition and thickness) so that the mirror selectively reflects only the beams of a given wavelength (according to a condition known as the Bragg condition, which links the reflectivity of the mirror to the wavelength of the incident beams).

In this variant, several filtering resources are used in series. The resource that is furthest upstream, which performs a selective deflection of beams and their recovery, provides protection for the resource furthest downstream (the multi-layer mirror) from the debris emitted by the source.

Note finally that it is possible to implement the invention in a device that includes a multiplicity of sources of initial radiation, each associated with resources that can be used to control a distribution of the refraction index in an associated control region.

This mode of implementation is illustrated diagrammatically in figure 4.

In this figure, a multiplicity of chambers 21i which are similar to the chamber 21 already described, direct their respective radiation along respective median lines Ai, which converge toward a central optic 23.

The central optic can thus receive the beams emitted by one or more chambers 21i, according to the chambers that are active.

The distance between the optic 23 and each chamber is adjusted to select the radiation filtering wavelength associated with each active chamber.

It is also thus possible to cause beams of different wavelengths, coming from different chambers, to arrive at the optic 23.

In any case, the optic 23 is able to redirect the received beams toward the exterior, and therefore toward other optical processing resources (such as a lithography mask) for example.